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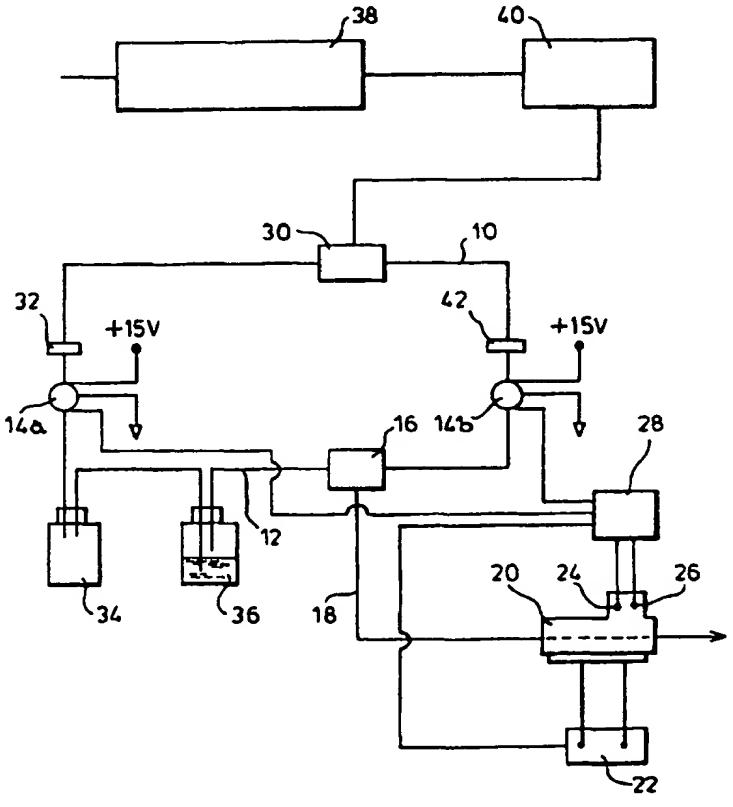
(54) Title: HUMIDITY GENERATOR

(57) Abstract

There is disclosed a humidity generator comprising: means for producing and conducting (10) a dry air flow; means for producing and conducting (12) a wet air flow; variable ratio mixing means (14a, 14b, 16) for mixing the wet and dry air flows to produce a combined air flow of selectable relative humidity; means for conducting (18) the combined air flow; a temperature selectable thermostatic enclosure (20) enclosing a portion of the combined air flow; relative humidity sensing (24) means positioned within said enclosure; temperature sensing means (26) positioned within said enclosure; and feedback control means, wherein the feedback control means (28) controls the temperature of the thermostatic enclosure (20) in response to the output of the temperature sensing means (26) so as to maintain a constant enclosure temperature, and controls the variable ratio mixing means in response to the output of the relative humidity sensing means (24) so as to maintain a constant combined air flow relative humidity.



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HUMIDITY GENERATOR

This invention relates to humidity generators, in particular to a generator capable of producing air flows of a precise humidity.

There are many applications in which it is desirable to produce an air stream of constant humidity. One such example is in the evaluation and characterisation of various sensors, particularly when the sensor is intended for use in ambient conditions, such as in atmospheric monitoring systems, where the sensor must be sufficiently robust to withstand the variations in humidity inevitably encountered in these applications. Saturated salt solutions can produce atmospheres of standard relative humidity (see, for example, K M Ganzer and R Rebenfield, Am.Lab., 19 (1087) 40), as can a number of commercially available humidity generators which involve mixing flows of wet and dry air, with control of the relative humidity being achieved through control of the mixing ratio. However, humidities cannot be controlled precisely by these methods since rigorous control of a user selected operating temperature is not possible.

The present invention provides a precise, relatively low-cost humidity generator.

According to the invention there is provided a humidity generator comprising :

means for producing and conducting a dry air flow;

means for producing and conducting a wet air flow;

variable ratio mixing means for mixing the wet and dry air flows to produce a combined air flow of selectable relative humidity:

means for conducting the combined air flow;

a temperature selectable thermostatic enclosure enclosing a portion of the combined air flow;

relative humidity sensing means positioned within said enclosure;

temperature sensing means positioned within said enclosure; and

feedback control means;

wherein the feedback control means controls the temperature of the enclosure in response to the output of the temperature sensing means so as to maintain a constant enclosure temperature, and controls the variable ratio mixing means in response to the output of the relative humidity sensing means so as to maintain a constant combined air flow relative humidity.

The feedback control means may comprise Proportional Integral Differential devices (PIDs).

Alternatively the feedback control means may comprise a neural network or a fuzzy logic algorithm.

The variable ratio mixing means may comprise proportional valves, which may be fluistor valves.

The variable ratio mixing means may further comprise a three way mixing zone into which the dry air and wet air flows feed.

The wet air flow may comprise a splitter for splitting the dry air flow into two air flows and a water bubbler through which one of the air flows generated thereby is passed. A proportional valve may be positioned upstream of the water bubbler and a water trap may be positioned between this proportional valve and the water bubbler.

Alternatively the means for producing a wet air flow may comprise a splitter for splitting the dry air flow into two air flows and a length of nafion® or like

tubing through which one of the air flows generated thereby is passed, the external surface of said tubing being exposed to a wet environment.

The humidity generator may further comprise pressure regulation means for maintaining a substantially constant combined air flow pressure.

The pressure regulation means may comprise a pressure release valve, and the pressure of the combined air flow upstream of the pressure regulation means may exceed the pressure at which the pressure release valve operates.

The feedback control means may control the pressure regulation means so as to maintain a substantially constant combined air flow pressure. The pressure regulation means may comprise a fluistor valve.

At least one air filter may be positioned upstream of the proportional valves.

The dry air flow may be produced by pumping air through air drying means.

The conducting means may be flexible tubing.

Humidity generators in accordance with the invention will now be described by way of example only and with reference to the accompanying drawings in which :-

Figure 1 is a schematic diagram of a first embodiment of the invention;

Figure 2 is a schematic diagram of a second embodiment of the invention; and

Figure 3 is a side view of a humidity assembly.

Figure 1 shows a first embodiment of a humidity generator of the present invention which comprises :

means for producing and conducting 10 a dry air flow;

means for producing and conducting 12 a wet air flow;

variable ratio mixing means 14a,14b, 16 for mixing the wet and dry air flows to produce a combined air flow of selectable relative humidity;

means for conducting 18 the combined air flow;

a temperature selectable thermostatic enclosure 20 enclosing a portion of the combined air flow;

relative humidity sensing means 24 positioned within the enclosure 20;

temperature sensing means 26 positioned within the enclosure 20; and

feedback control means 28;

wherein the feedback control means 28 control the temperature of the enclosure 20 in response to the output of the temperature sensing means 26 so as to maintain a constant enclosure temperature, and controls the variable ratio mixing means 14a,14b in response to the output of the relative humidity sensing means 24 so as to maintain a constant combined air flow relative humidity.

The relative humidity sensing means 24 and temperature sensing means 26 are standard, commercially available sensors, whilst the thermostatic enclosure 20 is a metal block heated resistively by an electrical supply 22. However, operation at or below ambient temperature - with an appropriate cooling system - is within the scope of the invention. A peltier system can be used for this purpose.

The use of PIDs in the feedback control means 28 has been found to be particularly advantageous, this method of feedback permitting precise control of enclosure temperature and relative humidity. Precisions of ± 0.2°C and ± 0.2%, respectively, are obtained. The PIDs can be operated in software or in hardware. Other forms of feedback control, such as neural networks or fuzzy logic algorithms, are also within the scope of the invention.

The control of relative humidity is achieved by mixing the wet air flow with the dry air flow with controlled mixing ratios. It has been found this control over the mixing ratio is advantageously accomplished with fluistor valves 14a,14b, although other examples of proportional valves, such as mass flow controllers, may alternatively be employed. In the preferred (but not-limiting) embodiments, the variable ratio mixing means comprises the fluistor valves 14a,14b and a three way mixing block 16 into which the dry air and wet air flows feed and the combined air flow emerges. In the first embodiment, the wet air flow is produced by splitting the dry air flow into two air flows via a three way block 30 and passing one of the air flows generated thereby through an air filter 32, a fluistor valve 14a, a water trap 34 and a water bubbler 36. This positioning of the fluistor valve 14a upstream of the water bubbler 36 with the water trap 34 interposed has been found to offer best protection to the valve from the deleterious effects of water vapour.

The dry air flow 10 is produced by pumping air through a dryer 38 with a pump 40, although it is also possible to employ a pressurised gas supply. An air filter 42 is positioned in the dry air flow 10 upstream of the fluistor valve 14b.

Flexible tubing is conveniently employed as conducting means 10, 12, 18, however, any suitable form of piping or conduits may be used. The operating conditions should be considered when selecting appropriate conducting means. For example,

operation at low humidities requires the use of low absorbance materials such as stainless steel tubing.

Figures 2 and 3 depict a second embodiment in which a different method of producing the wet air flow is employed. Figure 2 is a schematic diagram of the manifold. It should be noted that identical numerals in Figures 1 and 2 describe identical components. In fact, a large number of components are shared by the two embodiments. For reasons of clarity the PID feedback control system is not shown in Figure 2; however, it controls the fluistor valves 14a,14b in identical fashion to that described above in relation to Figure 1. Similarly, the electrical supply 22 is not shown in Figure 2.

The principle difference is the wet air flow is produced by splitting the dry air flow into two air flows and passing one of the air flows generated thereby through a humidity assembly 42 which comprises a length of nafion® or like tubing 44, the external surface of said tubing 44 being exposed to a wet environment. Figure 3 shows the humidity assembly 42 in greater detail. One of the split dry air flows enters the assembly 42 via a suitably adapted inlet port 46 to which is connected the nafion® tubing 44. The other end of the nafion® tubing is connected to a suitably adapted outlet port 48, from which the now wet air flow is sent to the three way mixing block 16. The nafion® tubing is contained within a U bend 49 which is partly filled with water 50 via a water inlet port 52. Water may be drained via a water drain 54. Nafion® membranes are well known for the efficient and selective transportation of water across the membrane which occurs whenever a humidity gradient is generated. "Like" tubing, for the present purposes, is considered to be tubing which transports water in similar manner. In contrast to the previous embodiment, which employed a water bubbler, the water source is now kept outside of the manifold system. This is a considerable advantage, since it minimises damage to the manifold caused by continual exposure to water vapour

and condensed water droplets, eliminates the problems of "suck-back", and permits operation at pressures well above atmospheric pressure.

Dry air may be introduced to the manifold via the pump/dryer system. A single air filter 56 is employed. The air supply is at ca. 23 psi positive pressure and the enclosure 20, which is a mixing block, is equipped with a pressure release valve 58 which is set to mechanically regulate the pressure to 20 psi. This ensures that an even flow rate of ca. 600 ml min^{-1} is maintained at outlet 60. It will be apparent that other combinations of air flow pressures and regulating pressures can be employed producing different outlet flow rates. Furthermore, it is possible to control the pressure regulation via the feedback control means. In this instance, an electronically controlled valve, such as a fluistor, may be employed. Control of the pressure is important since it permits the production of an air flow of precise absolute humidity (as defined in "A Guide to the Measurement of Humidity", 1996, National Physical Laboratory/Institute of Measurement and Control, London, UK).

The relative humidity and temperature sensors comprise a commercially available probe and PCB assembly 62 (Rotronics).

Prior art commercial humidity generators permit control of relative humidity, by mixing streams of dry and wet air in variable ratios. The direct measurement of temperature within the thermostatic enclosure 20 together with the ability to select the working temperature in the present invention permits precise humidity control. The relative humidity of the second embodiment is typically adjustable across the 2-80% range whilst the temperature of the enclosure is selectable across the range 25-35°C, dependent on the ambient temperature.

It will be appreciated that it is not intended to limit the invention to the above examples only, many variations, such as might readily occur to one skilled in the art, being possible without departing from the scope thereof. For example, lower operating temperatures may be achieved through the use of a cooling device, such as a peltier.

CLAIMS

1. A humidity generator comprising :

means for producing and conducting a dry air flow;

means for producing and conducting a wet air flow;

variable ratio mixing means for mixing the wet and dry air flows to produce a combined air flow of selectable relative humidity;

means for conducting the combined air flow;

a temperature selectable thermostatic enclosure enclosing a portion of the combined air flow;

relative humidity sensing means positioned within said enclosure;

temperature sensing means positioned within said enclosure; and

feedback control means,

wherein the feedback control means controls the temperature of the thermostatic enclosure in response to the output of the temperature sensing means so as to maintain a constant enclosure temperature, and controls the variable ratio mixing means in response to the output of the relative humidity sensing means so as to maintain a constant combined air flow relative humidity.

2. A humidity generator according to claim 1 in which the feedback control means comprises PIDs.

3. A humidity generator according to claim 1 in which the feedback control means comprises a neural network or a fuzzy logic algorithm.

4. A humidity generator according to any of claims 1 to 3 in which the variable ratio mixing means comprises proportional valves.

5. A humidity generator according to claim 4 in which the proportional valves are fluistor valves.

6. A humidity generator according to claim 4 or claim 5 in which the variable ratio mixing means further comprises a three way mixing zone into which the dry air and wet air flows feed.

7. A humidity generator according to claim 6 in which the means for producing a wet air flow comprises a splitter for splitting the dry air flow into two air flows and a water bubbler through which one of the air flows generated thereby is passed.

8. A humidity generator according to claim 7 in which a proportional valve is positioned upstream of the water bubbler.

9. A humidity generator according to claim 8 in which a water trap is positioned between the proportional valve positioned upstream of the water bubbler and the water bubbler.

10. A humidity generator according to claim 6 in which the means for producing a wet air flow comprises a splitter for splitting the dry air flow into two air flows and a length of nafion® or like tubing through which one of the air flows generated thereby is passed, the external surface of said tubing being exposed to a wet environment.

11. A humidity generator according to any of the previous claims further comprising pressure regulation means for maintaining a substantially constant combined air flow pressure.

12. A humidity generator according to claim 11 in which the pressure regulation means comprises a pressure release valve and the pressure of the combined air flow upstream of the pressure release means exceeds the pressure at which the pressure release valve operates.

13. A humidity generator according to claim 11 in which the feedback control means controls the pressure regulation means so as to maintain a substantially constant combined air flow pressure.

14. A humidity generator according to claim 13 in which the pressure regulation means comprises a fluistor valve.

15. A humidity generator according to any one of claims 4 to 10 in which at least one air filter is positioned upstream of the proportional valves.

16. A humidity generator according to any one of the previous claims in which the dry air flow is produced by pumping air through air drying means.

17. A humidity generator according to any of the previous claims in which the conducting means are flexible tubing.

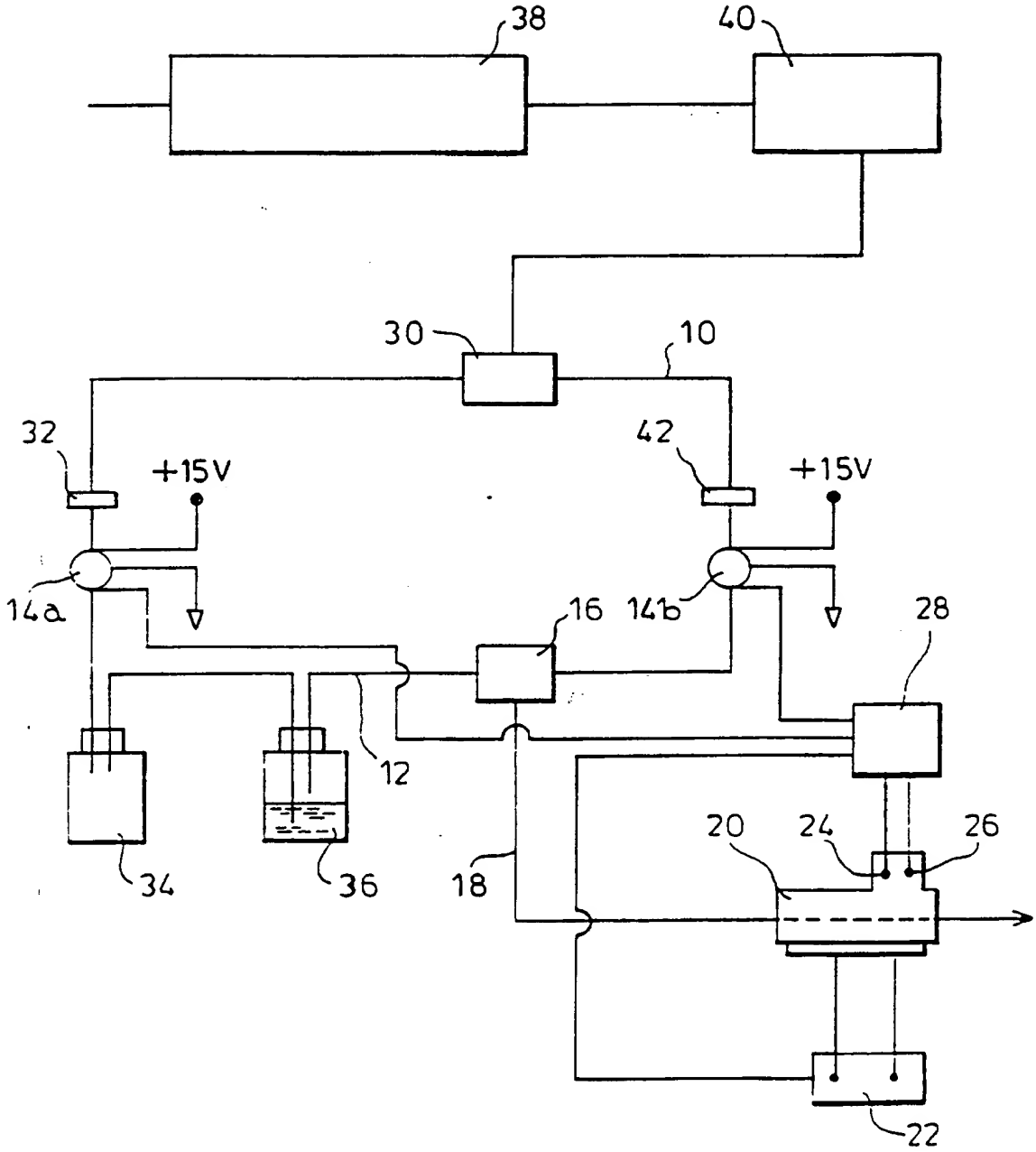

FIG.1

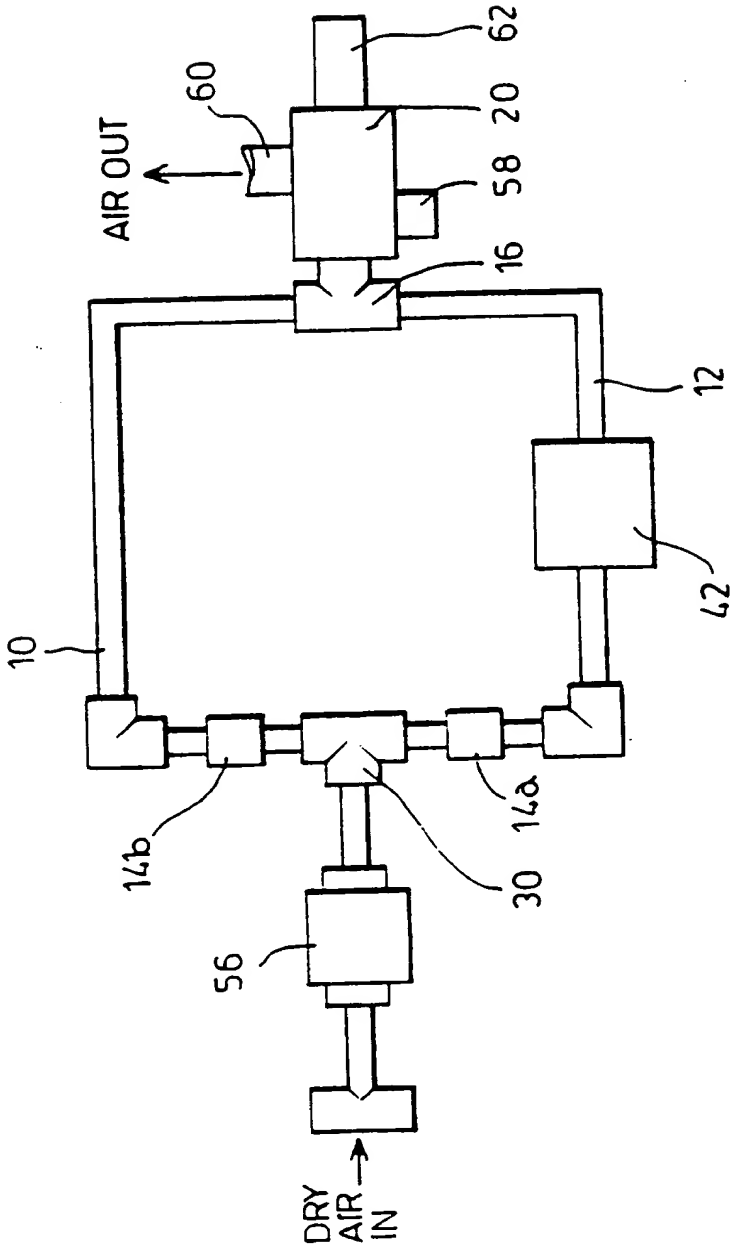

FIG.2

INTERNATIONAL SEARCH REPORT

Information on patent family members

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